Research Note 81-23

FIELD EVALUATION OF THE ESSLR AND CESSLR DEVICES

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The range estimation capabilities of two eye-safe filters (densities of 2.9 and 5.5) for the M60A3 rangefinder were evaluated under specified conditions of target distance, target reflectivity, and target angle. Both filters were able to range targets out to at least 2000m when targets were enhanced with appropriate reflective materials. While both filters may be useful in tank gunnery training, only the 5.5 density filter can be used in freeplay exercises based on safety conditions.

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Training Simulation

Foreword

The Fort Knox Field Unit has a long history of successfully using the methodology of experimental psychology for solving Army training systems problems. The simulation system team of this unit performs research and development on the effectiveness of devices, aids and simulations for improving Armor training.

Army tanks equipped with laser range finders are restricted in gunnery procedures training by eye safety hazards. Extremely large range safety fans are required to operate the laser range finder, and such ranges are unavailable at many locations, or available only for short periods at major training areas. As a result, crew practice is frequently insufficient to ensure accurate ranging in various combat conditions. One potential solution is to provide filters for the range finder emissions that reduce or eliminate possible damage to the eyes of soldiers or bystanders during training.

This report describes the results of research conducted to determine whether simple light filter devices used to prevent eye damage interfere with the effective use of the laser range finder and typical tank gunnery exercises. The filters studied were found to permit accurate laser ranging when used with reflective materials enhancing the laser energy retained from gunnery targets. The proper implementation of laser filter equipment and reflective material will improve current gunnery training programs and subsequent tank crew performance. The results of this research have implications for USAARMC and PM TRADE decisions on devices that will provide safe and effective training of armor crews.

FIELD EVALUATION OF THE ESSLR AND CESSLR DEVICES

BRIEF

Requirement:

Tanks that are equipped with Laser Rangefinders (LRF) are restricted because of the need for large range safety fans. As a result, the use of the LRF in training is severely limited. Two filters have been designed to solve the eye safety hazard. One filter, Eye-Safe Simulated Laser Rangefinder (ESSLR) is completely safe; the other, Conditionally Eye-Safe Simulated Laser Rangefinder (CESSLR) is safe beyond a specified distance. Either filter can be mounted across the exit window of the LRF. The range estimation capability of the LRF with each filter was assessed under specified conditions of target distance, target reflectivity, and target angle. The evaluation was conducted under the TRADOC CEP program to verify the operating parameters projected from the results of an earlier engineering test, and to provide a basis for evaluation of the device by the proponent, the US Army Armor Center, Directorate of Training Developments.

Procedure:

Data gathering focused on those combinations of factors believed most likely to test the limits of each device. These reflective materials were added to 8' X 8' basic panel targets: (1) unenhanced (no materials added); (2) uncoated sheeting, 2" wide, 12" apart; (3) coated sheeting, 2" wide, 12" apart; (4) molded plastic discs, 3" diameter, 12" apart; and (5) corner cube prism, 2 3/4" diameter, center of target. Data collection consisted in measuring the unfiltered beam output, mounting the filter (ESSLR or CESSLR), orienting the target in distance and angle, and instructing the gunner to range the target. A criterion of 22 correct (within 10m) rangings in 22 estimations was set. This represents a 90% confidence level for a 90% probability of correct ranging at a given target distance.

Findings:

CESSLR ranged satisfactorily to targets enhanced by strips of reflective (coated or uncoated) material at ranges of 1150 to 2000m. Performance with targets <1150m can be assumed, but performance with targets >2000m remains to be verified. CESSLR also ranged satisfactorily to

unenhanced targets at ranges of at least 1150m. In contrast, ESSLR did not range to unenhanced targets at any range. ESSLR ranged to targets enhanced by reflective (coated or uncoated) material out to a range of at least 1340m, and a corner cube prism at a range of 2000m.

Utilization:

In light of their demonstrated effects on LRF operation, safety, and ease of mounting on the LRF, both filters permit practice on laser ranging during tank gunnery exercises. The present findings indicate effective types of reflective materials for each filter at typical target distances. Correct implementation of filters and materials on tank ranges will help to fill a significant void in current gunnery training programs.

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FIELD EVALUATION OF THE ESSLR AND CESSLR DEVICES

INTRODUCTION

PURPOSE AND SCOPE

The purpose of this report is to describe the results of a field evaluation of the Eye-Safe Simulated Laser Rangefinder (ESSLR) filter and the Conditionally Eye-Safe Simulated Laser Rangefinder (CESSLR) filter. The field evaluation was undertaken under the TRADOC CEP program prior to the conduct of Operational Test I to provide a basis for evaluation by the proponent, the US Army Armor Center, Directorate of Training Developments.

EVALUATION ISSUES

Several weeks before undertaking the evaluation, a tentative set of issues to be addressed by the inquiry was developed. These issues were drafted in March 1981 by representatives from USAARMC-DTD, Decilog, and HumRRO. Statements of these issues are provided in an Appendix attached to this report.

TEST OBJECTIVES

Objectives of the field evaluation were:

1. To assess the range estimation capability of the M60A3 rangefinder with the ESSLR filter device under specified conditions (such as target distance, target reflectivity, target angle, etc.).

2. To assess the range estimation capability of the M60A3 rangefinder with the CESSLR filter device under specified conditions (such as target distance, target reflectivity, target angle, etc.).

BACKGROUND

An earlier evaluation of the ESSLR filter device occurred in February

1981. Sponsored by PM-TRADE, and conducted by Decilog, Inc. with assistance of ARRADCOM and other agencies, this evaluation used only one target distance (975m). By a series of formulas, Decilog calculated the capabilities this filter would have at other ranges under various environmental conditions.

A remaining requirement was to evaluate both devices in an operational context. A preliminary CEP evaluation with each device installed in a tank, and with range estimation procedures being conducted by a regular tank crew, was believed necessary before the devices should be subjected to a full scale operational test. This evaluation could provide important clues to guide subsequent device testing, as well as provide information bearing on the potential usefulness of the devices in tank gunnery training.

SYSTEM DESCRIPTION

Tanks that are equipped with Laser Rangefinders (LRF) are severly restricted in their operation due to the extremely large safety fans required. Because of a lack of ranges with this capability, the use of the LRF in training is severly limited. As a consequence, crews are not adequately trained in reducing the number of multiple returns and discriminating between them. In addition, gunnery training accomplished without the LRF is incomplete and inaccurate in that it leaves a critical task undone.

Decilog, Inc. designed two laser filter assemblies to solve the eye safety hazard associated with the M60A3 AN/VVG-2 Laser Rangefinder. Made of glass, one filter (density 5.5) is completely eye safe; the other filter (density 2.9) is conditionally eye safe, i.e., safe beyond a specified distance. Each device can function more effectively if targets are enhanced with retroreflective materials. A support bracket is required to mount a filter, and the bracket and filter are mounted across the exit window of

the AN/VVG-2 rangefinder. Both devices were designed to range targets at distances of 200m to 3000m.

TEST LIMITATIONS

As will be discussed in the succeeding paragraphs, a sizeable number of conditions or factors warranted inquiry. However, because the availability of a suitable range was limited, only selected combinations of factors could actually be investigated. In addition, the maximum target distance on the available range was only 2000m; thus, capabilities of the device to range beyond that point could not be determined.

EVALUATION PROCEDURES

1. Dates of Evaluation. The evaluation took place during the period 22 June through 2 July 1981.

2. Site of Evaluation. The evaluation site was the McFarland-Oliver range located at Fort Knox, Kentucky.

3. Participating Organizations. Personnel from the following organizations particpated in the effort.

   a. US Army Armor Center, Directorate of Training Developments, Fort Knox.

   b. US Army Research Institute, Fort Knox Field Unit, Fort Knox.

   c. Decilog, Inc., Melville, New York.

   d. Human Resources Research Organization, Military Training Research Division, Fort Knox.

4. Equipment and Material. The following equipment and material were employed in conducting the evaluation.

   a. 2 M60A3 tanks, equipped with AN/VVG-2 LRF, plus crews.

   b. 1 Improved TOW Vehicle (ITV), with crew.

c. 4 8' X 8' panel targets.

d. Radiometer Indicator Unit, Model 581-15, mfd by EG&G, Electronic Optical Division, Salem, MA.

e. ESSLR and CESSLR filters, plus Gain Enhancement Plug.

f. Retroreflectors and reflective materials.

g. Record forms to record range estimation and related data.

5. Variables of Interest. Before describing variables in the eval- uation, it may be emphasized that the general question concerned t con- ditions that limit the use of the ESSLR and CESSLR in laser rangin d gunnery training on subcaliber and main gun ranges. In preparing a -cific plan for the field evaluation of the two devices, it was apparent that many variables were relevant and susceptible to control or manipu- lation. These included:

a. Device -- ESSLR, CESSLR.

b. Target reflectivity -- unenhanced, uncoated, coated, molded plastic, corner prism.*

c. Spacing of reflective materials -- from 2" to 16" (approx- imately).

d. Angle of target with respect to sight -- 0° to 45° (approx- imately).

e. Aim point -- center of mass, base of target.

f. Target distance -- 200m to 2000m.

6. Test Rationale. In light of these many variables, and because of the limited period during which a range would be available, the deci- sion was made to focus data gathering on those combinations of variables

*Reflectivity conditions used in the evaluation are more fully described later.

believed most likely to test the limits of each device. If a device could perform well in a "severe" situation, there would be little need to test its capability under less stringent conditions. For example, if a device ranged accurately to an unenhanced target at 2000m placed at an angle of 45°, there would seem to be no need to test the device at 30° or less. On the other hand, if the device did not range reliably in the original situation, less stringent conditions would need to be tried until the device ranged satisfactorily.

The plan was to establish the limits of performance of each device at both near and far ranges. If these points could be established, device performance at intermediate ranges could be reasonably inferred. That rationale, in general, was used to guide data gathering during the evaluation.

7. Performance Criterion. Prior to beginning the collection of ranging data, a performance of 22 consecutively correct rangings was set as the criterion. This value represents a 90% confidence level for a 90% probability of correct ranging at a given target distance. A return was considered to be correct if it was within 10m of the actual distance.

8. Test Sequence. As noted earlier, one tank range was made available for evaluating the two devices. The fact that there was only one range, plus the fact that attachment and removal of the filters was simple and quick, enabled the collection of data from either device without delay.

9. Target Enhancement. Targets were enhanced with reflective materials and devices immediately prior to their use. Each panel target was prepared of 1/4" plywood and was painted in lusterless olive drab. The specific target reflectivity conditions described below were superimposed on the basic target.

a. Unenhanced. This target was not enhanced with any reflective materials. It remained as orginally painted.

b. Uncoated Sheeting (3M High Gain Sheeting No. 7210). This sheeting was 2" wide, and it was placed vertically on the basic target so that 7 strips resulted. The strips were placed 12" apart, center to center, and each strip was approximately 8' long. The sheeting was stapled to the basic target so that it might be easily removed if necessary.

c. Coated Sheeting (Scotchlite High Intensity Sheeting No. 3870). This sheeting was also 2" wide, and it was placed vertically on the target (7 strips, 12" apart). It was stapled to the basic target.

d. Molded Plastic Discs (3M Reflectolite Reflectors). These 3" diameter discs were positioned on the basic target so that they produced 5 rows and 6 columns. They were spaced such that the center of one disc was 12" from the center of an adjacent disc. The discs were glued to the plywood.

e. Corner Cube Prism (2 3/4" diameter, Valtec No. V101). One corner cube prism was mounted in the center of a basic target.

10. Data Collection Steps. In general, the following set of steps was performed regardless which device was being evaluated.

a. Measure unfiltered laser beam output. Except for the first day, when measuring equipment was not available, and on the last day, when there was no electrical power at the site, the unfiltered laser beam output was measured at the start and end of each day of data collection. This measurement was made to insure that adequate beam power was available. Output was also measured at midday occasionally to confirm that the laser output was still satisfactory. Laser safety goggles were worn when measuring beam output.

b. Mount the filter. Immediately after power was measured, the ESSLR or CESSLR filter was attached, depending on which device was needed. Since the filter assembly was color coded (red, CESSLR; green, ESSLR), and a convenient support bracket was provided, it was a simple matter to select and mount the filter. A Gain Enhancement Plug (GEP) was installed at the same time. Its purpose was to inhibit the Time Programmed Gain of the rangefinder, and thereby provide maximum receiver sensitivity for all ranges. The GEP was used only when the beam was filtered.

c. Instruct the Gunner. A person to record the data positioned himself near the gunner to communicate instructions to the gunner (where to lay on target, when to lase a target, etc.). The gunner also transmitted instructions by radio to the ITV crew regarding target placement. For convenience, the gunner ranged on targets using the tank commander's sight. This enabled him to view the range readout.

d. Place and Orient Targets. Because of high weeds and brush, targets were mounted vertically on the rear ramp of the ITV for ranging. Only one target was ranged at any one time. Orientation (angle) of the target face with respect to the tank was controlled with the aid of the azimuth indicator and ITV sighting system. Distance of the target from the tank was managed by using range markers and by having the gunner lase on fixed objects with the unfiltered rangefinder before data collection began.

e. Maintain Range Estimation Record. A special record sheet was employed to record the testing conditions and lasing results. A copy of this record sheet is provided on page 9. Conditions were held constant throughout each series of lasings. After each lasing, the gunner reported the results: no return, multiple returns, or one return, as appropriate.

He then reported the numerical value associated with the return. This value (or values) was noted on the record sheet. The visibility level and sky condition were judged at the beginning of each record.

ESSLR/CESSLR Evaluation
Record Sheet

Phase__________ Actual Target Distance__________

Aim Point__________ Date__________ Type of Range__________

Target Angle__________ Time Begin__________ Time End__________

Reflectivity__________

Visibility__________ Gunner__________

Evaluation Issues__________

Target Distance Reported. If multiple returns, give all distances.

	1st	2nd	Last		1st	2nd	Last
1				16			
2				17			
3				18			
4				19			
5				20			
6				21			
7				22			
8				23			
9				24			
10				25			
11				26			
12				27			
13				28			
14				29			
15				30			

FINDINGS RELEVANT TO BOTH CESSLR AND ESSLR

Data collection proceeded in blocks or clusters of range estimations, first with one device and then with the other. The following sequence of clusters was employed.

Clusters of Record Sheets	Device
17	CESSLR
7	ESSLR
5	CESSLR
21	ESSLR

Because the filters were easy to install and remove, the shift from one device to the other involved only a minimum of disruption. Changing the location or angle of a target, in contrast, was generally very time consuming. The use of the azimuth indicator on the ITV, however, permitted accurate orientation of the target to the sight.

A judgement of the visibility level and sky condition that prevailed each day is shown in Table 1. These factors held constant on some days, and changed on others. Neither rain nor fog was experienced during the evaluation.

TABLE 1

Judged Visibility and Sky Condition during Evaluation

Day	Visibility Level in Km	Sky Condition
1	10	clear
2	10	clear
3	(no data collection)	
4	5-10	slight haze; clear
5	10	clear
6	5-10	slight haze
7	5	moderate haze
8	5-10	slight haze; clear
9	3-5	definite haze; overcast

Table 2 relates Observation Day, Record Sheet Nos. and Laser Power for the entire period of the evaluation.* Of particular interest is

TABLE 2

Laser Beam Output For Each Day

Observation Day	Record Sheet Nos.	Laser Power in m-joules
1	1-3	40**
2	4-9	40-15
3	None, LRF being replaced	
4	10-16	45-60
5	17-24	45-58
6	25-30	45-52
7	31-32	47
8	33-44	42
9	45-50	42**

**Assumed, not actually measured.

the change in beam output on Day 2. While the output at the start of the day was presumably adequate, a sizeable drop appeared by the day's end. As will be discussed later, this drop may account for the poor range estimation performance that was observed on Day 2. The LRF was replaced on Day 3, and in contrast to the drop on Day 2, an increase in beam output was measured at the end of Days 4 thru 6.

*These measurements pertain to the LRF in tank 27. The LRF in the second tank (16) yielded zero output. The LRF in tank 27 was replaced on Day 3 because of low power output and all subsequent rangings were made using tank 27. Thus, tank 16 is not represented in Tables 1 or 2.

EVALUATION OF CESSLR DEVICE

RESULTS

A presentation of the raw data of the range estimation performance of the CESSLR device is provided in Table 3. Study of this table will show that some 459 range estimations were made with the device. In 13 of 22 records, the device achieved the criterion of being within 10m in 22 out of 22 estimations. A total of 15 multiple returns were reported, and they all appeared in only 4 records. In 12 of these 15 instances, the aim point was base of target.

Some record sheets show less than 22 estimations. Sheet No. 2, for example, has only 5 estimations, all of which yielded "no return." It was decided at that time that ranging at an angle of 45° was not productive because of these "no returns." To see if this was caused by target angle, a shift to 30° was made, at which point acceptable performance was obtained. At other times of poor ranging performance (e.g., Sheet Nos. 8 and 25a), a similar shift in angle or range was employed to explore if criterion could be attained.

Another kind of shift is seen on Sheet Nos. 3a and 3b. This represents an instance in which an effort was made to shift midway in a collection series from aim point center of mass (CM) to base of target (BT) and still maintain criterion performance. This shift was never attempted unless the first 11 estimations were all acceptable. While this procedure does not technically permit claiming criterion, it conserved the work load and facilitated moving on to other critical conditions.

On two occasions when range estimation performance by the CESSLR was poor, repeated rangings under the same conditions at a later time

TABLE 3

Range Estimation Performance of the CESSLR Device

Record Sheet No.	Tgt. Dist.	Tgt. Type	Tgt. Angle	Aim Point	Ratio Correct/ to Total	No. of Multiple Returns
1	2000	coated	0°	CM*	22/22	0
2	2000	coated	45°	CM	0/5	0
3a	2000	coated	30°	CM	11/11	0
3b	2000	coated	30°	BT*	11/11	0
4	940	unenhanced	45°	CM	15/22	0
5	940	unenhanced	45°	BT	19/22	0
6	940	unenhanced	30°	CM	13/22	0
7	940	unenhanced	0°	CM	18/22	0
8	840	unenhanced	0°	CM	1/6	0
9	550	unenhanced	0°	CM	9/22	0
10	905	unenhanced	0°	CM	22/22	0
11	905	unenhanced	45°	CM	22/22	0
12	1150	unenhanced	45°	CM	22/22	0
13	1150	unenhanced	45°	BT	22/22	0
14	2000	molded	45°	CM	22/22	0
15	2000	coated	45°	CM	22/22	0
16	2000	unenhanced	45°	CM	10/22	0
17	2000	unenhanced	0°	CM	3/22	0
25a	2000	uncoated	45°	CM	2/8	0
25b	2000	uncoated	30°	CM	22/22	0
26	1150	uncoated	45°	CM	22/22	0
27	1150	coated	45°	BT	22/22	1
28	1150	molded	45°	BT	22/22	0
29	2000	uncoated	45°	CM	22/22	0

* CM = Center of Mass
  BT = Base of Target

were able to achieve criterion. Record Sheet Nos. 2 and 15 represent one instance, Sheet Nos. 25a and 29 another. While it is tempting to explain Nos. 2 and 15 in terms of laser beam output, that explanation is not relevant for Nos. 25 and 29.

A check of Table 2 shows that a sizeable drop in beam output appeared on Day 2. Record Sheets relevant to that day are Nos. 4-9. Inspection of Sheet Nos. 4-9 on Table 3 shows that all of these estimations failed criterion. It seems apparent, therefore, that low beam output was responsible for the poor performance on that day. Low beam output, however, does not account for the other poor performances.

On Days 1 and 2, a minimum time of 20 sec. between successive lasings was used. Subsequently, however, because of the power drop on Day 2, the time between lasings was increased to approximately 40 sec. No power drops were observed after the original LRF was replaced, and after the time between lasings was increased.

Because the capability of the CESSLR was presumed to be several times greater than the ESSLR, evaluation activities with the CESSLR centered more on relatively far rather than near ranges. This is consistent both with its zone of safety (300m unaided viewing distance; 3100m aided viewing), and its likely use in a training situation. Some information about near range performance of the CESSLR was sought on Day 2, but this was done primarily because performance was declining and there was a need to understand if this was characteristic of the LRF in general or of this particular LRF.

EVALUATION ISSUES

Only certain of the evaluation issues listed in the Appendix are

relevant to the CESSLR. Each relevant issue is listed below, followed by a statement of the outcome of the issue based on the evaluation.

2. Does the CESSLR meet TM Med 279 protection standard for intra-beam viewing at finite viewing distances?

   Outcome: Device was given a Safety Release by US Army Environmental Hygience Agency, Aberdeen, MD.

3. Using the CESSLR, can returns be obtained reliably from unenhanced scaled range targets out to 600 meters?

   Outcome: Uncertain, because laser beam power was falling when this distance was ranged. However, the capability of CESSLR to range unenhanced targets at 905m and 1150m suggests similar results at 600m.

4. Using the CESSLR, can returns be obtained reliably at angles of incidence up to 20° from unenhanced scaled range targets out to 600 meters?

   Outcome: Uncertain, because laser beam power was falling when this distance was ranged. However, the capability of CESSLR to range unenhanced targets at 905m and 1150m suggests similar results at 600m.

5. Using the CESSLR, are partial-beam returns (sight on edge of target) from unenhanced scaled range target in the 200-600 meter range more frequently obtained than with the full power LRF?

   Outcome: Unknown, information about the capability of the full power LRF not obtained. Also, no information with respect to CESSLR.

10. Does the destruction of retroreflective material by live fire create a need for more-frequent-than-normal repair or replacement of targets?

    Outcome: Unknown, live fire was not employed.

11. Are the coated and uncoated retroreflective sheeting equally suspectible to damage from handling and live fire?

    Outcome: With respect to handling, the materials appear equally susceptible to damage. Live fire was not employed.

12. Does the coated and uncoated retroreflective sheeting produce unrealistic and distracting specular effects (flashes of reflected light)?

    Outcome: No specular effects were observed.

13. Out to what range can returns be reliably obtained with the CESSLR on diffuse (unenhanced) live-fire-range-type targets at 0° to 20° incidence?

    Outcome: Out to at least 1150m at angle of incidence of 45°, aiming at either center of mass or base of target.

14. Out to what range can returns be reliably obtained with the CESSLR from live-fire-range-type targets enhanced with retroreflective sheeting (coated or uncoated) and positioned at 0° and 20° incidence?

    Outcome: Out to at least 2000m at angle of incidence of 45°, aiming at center of mass.

15. Out to what range can returns be reliably obtained with the CESSLR from live-fire-range-type targets enhanced with molded plastic (bicycle type) retroflectors and positioned at 0° and 20° incidence?

    Outcome: Out to at least 2000m at angle of incidence of 45°, aiming at center of mass.

16. Will a target, arrayed with the minimum retroreflective material necessary to deliver reliable returns at long range, have unenhanced areas or "dead spots" which, because of the narrower beam, would fail to produce a return at shorter range?

    Outcome: Yes; gunner demonstrated easily an ability at 200m to lase on or off retroreflective material when it was 2" wide and spaced 12" apart.

17. Does the use of retroreflective materials excessively enhance target detectability, thus limiting the training value of free-play exercises?

    Outcome: Possibly; gunner can easily see retroreflective material with his sight.

22. Can multiple returns be produced with either the ESSLR or the CESSLR, with enhanced or unenhanced targets?

    Outcome: Occasional multiple returns were received with the CESSLR; 11 of 15 instances were with unenhanced targets, the remaining 4 with enhanced targets.

SUMMARY

A summary of the range estimation capability of the CESSLR as determined by the present evaluation activities is presented in Table 4. This table relates target reflectivity, target distance, and angle of incidence of target. Only those ranges (target distances) for which substantive

information is available are included. Thus, while the CESSLR can probably estimate target ranges at greater and lesser distances than those shown in the table, the present evaluation lacks definitive information about such distances. Consistent with the rationale expressed earlier, the existence of criterion performance at an angle of 45° enabled an assumption of criterion performance at angles less than 45°.

TABLE 4

Summary of
Range Estimation Capability of the CESSLR

Target Reflectivity	Range (m)	Angle of Incidence 0°	15°	30°	45°
Unenhanced	905	+	+	+	+*
	1150	+	+	+	+
	2000	-	-	-	-
Coated 2" strips, 12" apart	1150	+	+	+	+
	2000	+	+	+	+
Uncoated 2" strips, 12" apart	1150	+	+	+	+
	2000	+	+	+	+
Molded 3" discs, 12" apart	1150	+	+	+	+
	2000	+	+	+	+

*Meaning of symbols:
+ correct range estimations consistently received
- device failed to obtain consistent returns

Since only one spacing of reflective materials was used, no summary comments about this factor were included in Table 4. The situation with respect to aim point is slightly different. There were some data to suggest that multiple returns are more likely when aim point is base of target, but summary comments about the role of aim point seem premature.

EVALUATION OF THE ESSLR DEVICE

RESULTS

A presentation of the raw data of the range estimation performance of the ESSLR device is provided in Table 5. A total of 510 range estimations were made with the device. In 13 of 28 records, the device achieved the criterion of estimating range within 10m in 22 out of 22 times; this included observations on three record sheets in which a shift was made midway in a collection series from aim point CM to BT. No multiple returns were received.

Several record sheets contain less than 22 estimations. As reported for the CESSLR, some of these records resulted from efforts to identify where (under what conditions) criterion might be achieved. Sheet 20 is such an instance; a shift in target angle from 45° to 30° yielded criterion. In other instances (e.g., sheets 18 and 32), ranging was discontinued because performance was poor, and it was believed that little or no additional information would result from continued ranging under these conditions.

A special situation prevailed in Record Sheet Nos. 33, 34, and 35. In each case the gunner was able to lay his sight on or off the reflective material, and, depending on which was employed, he either received or did not receive a return. Thus, there seemed little point in continuing this ranging. This on/off capability was not inviolate, however. On record 38, for example, even though the gunner sighted on and then off the reflective material, the results were not uniform. The target angle at this time was 45°, and this may have accounted for the mixed findings.

TABLE 5

Range Estimation Performance of the ESSLR Device

Record Sheet No.	Tgt. Dist.	Tgt. Type	Tgt. Angle	Aim Point	Ratio Correct/ to Total	No. of Multiple Returns
18a	200	unenhanced	0°	CM*	0/5	0
18b	250	unenhanced	0°	CM	0/5	0
19	900	coated	45°	CM	22/22	0
20a	900	molded	45°	CM	0/5	0
20b	900	molded	30°	CM	22/22	0
21	900	uncoated	45°	CM	22/22	0
22	1340	uncoated	45°	CM	22/22	0
23	1340	coated	45°	CM	22/22	0
24	1340	molded	30°	CM	20/22	0
30a	2000	uncoated	45°	CM	0/5	0
30b	2000	uncoated	0°	CM	19/22	0
31	2000	molded	0°	CM	22/22	0
32	2000	coated	0°	CM	1/8	0
33a	200	uncoated	0°	CM[1]	6/6	0
33b	200	uncoated	0°	CM[2]	0/4	0
34a	200	coated	0°	CM[1]	3/3	0
34b	200	coated	0°	CM[2]	0/3	0
35a	200	molded	0°	CM[1]	3/3	0
35b	200	molded	0°	CM[2]	0/3	0
36a	300	uncoated	45°	CM[2]	11/11	0
36b	300	uncoated	45°	BT[2]	11/11	0
37a	300	coated	45°	CM[2]	11/11	0
37b	300	coated	45°	BT[2]	11/11	0
38a	300	molded	45°	CM[1]	5/11	0
38b	300	molded	45°	BT[1]	6/11	0
39a	300	uncoated	60°	CM[2]	11/11	0
39b	300	uncoated	60°	BT[2]	11/11	0
40a	480	uncoated	0°	CM[2]	11/11	0
40b	480	uncoated	0°	BT[2]	8/11	0
41a	480	coated	0°	CM[2]	11/11	0
41b	480	coated	0°	BT[2]	10/11	0
42a	480	molded	0°	CM	11/11	0
42b	480	molded	0°	BT	9/11	0
43	2000	prism	0°	CM[1]	22/22	0
44a	2000	prism	45°	CM[1]	0/5	0
44b	2000	prism	30°	CM[1]	22/22	0

TABLE 5 (continued)

Record Sheet No.	Tgt. Dist.	Tgt. Type	Tgt. Angle	Aim Point	Ratio Correct/ to Total	No. of Multiple Returns
45a	200	prism	0°	CM^1	2/7	0
45b	300	prism	0°	CM^1	2/5	0
46	300	prism	45°	CM^1	0/5	0
47	485	prism	0°	CM^1	4/6	0
48	800	prism	0°	CM^1	10/12	0
49	1200	prism	0°	CM^1	22/22	0
50a	1200	prism	45°	CM^1	0/2	0
50b	1200	prism	30°	CM^1	22/22	0

CM* = Center of Mass, BT = Base of Target
CM^1 = gunner sighted on reflective material
CM^2 = gunner sighted off reflective material
BT^1 = gunner sighted on reflective material
BT^2 = gunner sighted off reflective material

The ranging results reported on Record Sheet Nos. 45 thru 48 warrant special comment. These sheets pertain to the use of the corner cube prism at distances of 200m to 800m. The range estimations provided by the device at these distances were erratic; some estimations were in gross error, others were simply absent. Only when the target distance was increased to 1200m were consistent results received.

Review of Table 2 shows that the laser beam output for all ESSLR observations was at an acceptable level. Therefore, none of the ESSLR findings can be attributed to low beam output.

EVALUATION ISSUES

Listed below are the evaluation issues that are relevant to the ESSLR. Following each issue is a statement of the outcome of the issue based on the evaluation.

1. Does the ESSLR meet TB Med 279 protection standard for intrabeam viewing with unfiltered optics at zero range?

   Outcome: Device was given a Safety Release by the US Army Environmental Hygiene Agency, Aberdeen, MD.

6. Using the ESSLR, can returns be obtained reliably from scaled range targets enhanced with retroreflective sheeting (coated or uncoated) out to 600 meters?

   Outcome: Yes.

7. Using the ESSLR, can returns be obtained reliably at angles of incidence up to 20° from scaled range targets enhanced with retroreflective sheeting (coated or uncoated) out to 600 meters?

   Outcome: Yes, including angles of 45°.

8. Using the ESSLR, are partial-beam returns (sight on edge of target) from an enhanced target in the 200-3000 meter range more frequently obtained than with the full power LRF?

   Outcome: Unknown; no data on capability of full power LRF were obtained.

9. With either the ESSLR or CESSLR, does the parallax between the LRF transmitter and receiver prevent reliable returns at ranges in to 200 meters?

   Outcome: No, assuming that the support bracket and filter are mounted according to specifications.

18. Can a tank or other type target vehicle be enhanced with a mix of retroreflective material so that returns can be reliably obtained with the ESSLR at ranges of from 200-3000 meters and with the target vehicle at any angle?

    Outcome: Unknown; mix of retroreflective material was not employed.

19. Out to what range can returns be reliably obtained with the ESSLR from a tank or other vehicular target enhanced with corner prism retroreflectors?

    Outcome: From 1200 to 2000m with target angle of 30°.

20. Out to what range can returns be reliably obtained with the ESSLR and normal TPG from a tank or other vehicular target enhanced with corner prism retroreflectors?

    Outcome: Unknown; normal TPG was not employed.

21. Without normal TPG will the "bounceback" phenomenon occur at near ranges with ESSLR return from targets enhanced with corner prism retroreflectors?

    Outcome: Yes, this phenomenon was observed.

23. What problems does support maintenance encounter in installing the ESSLR support bracket?

Outcome: None; it was necessary to drop out the LRF to install the support bracket, and this required 15 minutes.

24. What problems does the crew encounter in installing the ESSLR filter?

Outcome: None, it was simple to install.

25. Does main gun firing degrade the performance of the ESSLR bracket or filter?

Outcome: Unknown; live fire was not employed.

SUMMARY

A summary of the range estimation capability of the ESSLR as determined by the present evaluation activities is presented in Table 6. This table relates target reflectivity, target distance, and angle of incidence of target. Only those ranges (target distances) for which substantive information is available are included. Thus, while the ESSLR can probably estimate target ranges at intermediate distances, the present evaluation lacks definitive information about such distances. Consistent with the rationale expressed earlier, the existence of criterion performance at an angle of 45° enabled an assumption of criterion performance at angles less than 45°.

One result not included in Table 6 was the capability of the ESSLR to range to criterion on an uncoated target placed 300m distant at an angle of 60°. This angle was not attempted with any of the other materials.

Only one spacing of reflective materials was used with the ESSLR; thus, no summary comments about spacing are possible. A few record sheets (46 to 42 inclusive) permit direct comparison of the two aim points, and

the results favor CM to a slight extent. BT was not used in ranging on the single prism, since, as it was used here, that would not be a meaningful aim point.

TABLE 6

Summary of
Range Estimation Capability of the ESSLR

Target Reflectivity	Range (m)	Angle of Incidence 0°	15°	30°	45°
Unenhanced	200	-	-	-	-*
Coated 2" strips, 12" apart	200	+	?	?	?
	300	+	+	+	+
	480	+	?	?	?
	900	+	+	+	+
	1340	+	+	+	+
	2000	-	-	-	-
Uncoated 2" strips, 12" apart	200	+	?	?	?
	300	+	+	+	+
	480	+	?	?	?
	900	+	+	+	+
	1340	+	+	+	+
	2000	-	-	-	-
Molded 3" discs, 12" apart	200	+	?	?	?
	300	?	?	?	-
	480	+	?	?	?
	900	+	+	+	-
	1340	?	?	-	-
	2000	+	?	?	?
1 Corner cube prism mounted in center of target	200	-	-	-	-
	300	-	-	-	-
	480	-	-	-	-
	800	-	-	-	-
	1200	+	+	+	-
	2000	+	+	+	-

*Meaning of Symbols:

+ correct range estimations consistently received
- device failed to obtain consistent returns
? not tested; no information available

CONCLUSIONS

In light of their demonstrated effects on laser ranging, safety (within specified CESSLR limits), and ease of mounting on the M60A3, both filter devices may be useful in permitting practice on laser ranging during tank gunnery exercises. The data obtained in this evaluation permit the following conclusions:

a. CESSLR appears to be usable on a full or 1/2-scale range with targets enhanced by strips of reflective (coated and uncoated) material. Performance with targets at ranges less than 1150m can be assumed, but performance with targets greater than 2000m remains to be verified. Use of molded reflectors or corner prisms with CESSLR will only be required if reflective strips are not adequate to a range of 3000m.

b. CESSLR appears to be usable on a full or 1/2-scale range with unenhanced targets to a range of at least 1150m. Performance with targets at less than 900m can be assumed, but the distance at which returns begin to fail (between 1150 and 2000m) remains to be determined.

c. CESSLR would minimize the cost of reflective material on full or 1/2-scale ranges, since enhanced targets would only be required beyond the maximum range for use of unenhanced targets. Both unenhanced and enhanced targets can be placed at angles up to 45° from the line of sight.

d. ESSLR cannot be used with unenhanced targets at any range.

e. ESSLR appears to be usable with targets enhanced by reflective (coated or uncoated) material out to ranges of at least 1340m. The effects of target size and required spacing of material remain to be determined for each range scale. Use of molded reflectors with ESSLR should not be necessary on scaled ranges, since performance should be adequate at ranges to 1500m with some spacing of reflective strips less than or equal to the 12" used in this study.

f. ESSLR can be used on full scale ranges only if corner-cube prisms or some alternative is used to enhance targets beyond the maximum range for use of reflective strips. Returns from closely spaced strips or solid sheets of reflective material as an alternative to prisms remain to be investigated. Reflective strips or sheets are more effective than molded reflectors at greater target angles. Prisms are not useful at less than 1200m because of the bounceback phenomenon producing erroneous range values.

g. ESSLR is the only filter usable in freeplay exercises based on safety considerations. The proper mix and placement of reflective material or devices required to enhance target vehicles remains to be determined.

RECOMMENDATIONS

Both the CESSLR and ESSLR filters should undergo further operational testing. The tests should focus on those questions that remain unanswered in the present evaluation, primarily in relation to the target conditions above. Since the present evaluation provided only suggestive information about multiple returns, further testing should also address that matter. Comparison of the frequency of multiple returns with both filters and the unfiltered laser is needed so that the impact of such returns on training can be assessed.

Appendix

Evaluation Issues. A tentative list of issues to be addressed in the field evaluation of ESSLR/CESSLR follows:

1. Does the ESSLR meet TB Med 279 protection standard for intrabeam viewing with unfiltered optics at zero range?

2. Does the CESSLR meet TM Med 279 protection standard for intrabeam viewing at finite viewing distances?

3. Using the CESSLR, can returns be obtained reliably from unenhanced scaled range targets out to 600 meters?

4. Using the CESSLR, can returns be obtained reliably at angles of incidence up to 20° from unenhanced scaled range targets out to 600 meters?

5. Using the CESSLR, are partial-beam returns (sight on edge of target) from unenhanced scaled range target in the 200-600 meter range more frequently obtained than with the full power LRF?

6. Using the ESSLR, can returns be obtained reliably from scaled range targets enhanced with retroreflective sheeting (coated or uncoated) out to 600 meters?

7. Using the ESSLR, can returns be obtained reliably at angles of incidence up to 20° from scaled range targets enhanced with retroreflective sheeting (coated or uncoated) out to 600 meters?

8. Using the ESSLR, are partial-beam returns (sight on edge of target) from an enhanced target in the 200-3000 meter range more frequently obtained than with the full power LRF?

9. With either the ESSLR or CESSLR, does the parallax between the LRF transmitter and receiver prevent reliable returns at ranges in to 200 meters?

10. Does the description of retroreflective material by live fire create a need for more-frequent-than-normal repair or replacement of targets?

11. Are the coated and uncoated retroreflective sheeting equally susceptible to damage from handling and live fire?

12. Does the coated and uncoated retroreflective sheeting produce unrealistic and distracting specular effects (flashes of reflected light)?

13. Out to what range can returns be reliably obtained with the CESSLR on diffuse (unenhanced) live-fire-range-type targets at 0° and 20° incidence?

14. Out to what range can returns be reliably obtained with the CESSLR from live-fire-range-type targets enhanced with retroreflective sheeting (coated or uncoated) and positioned at 0° and 20° incidence?

15. Out to what range can returns be reliably obtained with the CESSLR from live-fire-range-type targets enhanced with molded plastic (bicycle type) retroreflectors and positioned at 0° and 20° incidence?

16. Will a target, arrayed with the minimum retroreflective material necessary to deliver reliable returns at long range, have unenhanced areas or "dead spots" which, because of the narrower beam, would fail to produce a return at shorter range?

17. Does the use of retroreflective materials excessively enhance target detectability, thus limiting the training value of free-play exercises?

18. Can a tank or other type target vehicle be enhanced with a mix of retroreflective material so that returns can be reliably obtained with the ESSLR at ranges of from 200-300 meters and with the target vehicle at any angle?

19. Out to what range can returns be reliably obtained with the ESSLR from a tank or other vehicular target enhanced with corner prism retroreflectors?

20. Out to what range can returns be reliably obtained with the ESSLR and normal TPG from a tank or other vehicular target enhanced with corner prism retroreflectors?

21. Without normal TPG will the "bounceback" phenomenon occur at near ranges with ESSLR return from targets enhanced with corner prism retroreflectors?

22. Can multiple returns be produced with either the ESSLR or the CESSLR, with enhanced or unehanced targets?

23. What problems does support maintenance encounter in installing the ESSLR support bracket?

24. What problems does the crew encounter in installing the ESSLR filter?

25. Does main gun firing degrade the performance of the ESSLR bracket or filter?